

Fourth Annual Conference on Carbon Capture & Sequestration

*Developing Potential Paths Forward Based on the
Knowledge, Science and Experience to Date*

MMV Technologies

Cavity Ringdown in MMV Technologies for Carbon Sequestration

Chuji Wang,

Susan T. Scherrer, M. John Plodinec, and Jeff Lindner

May 2-5, 2005, Hilton Alexandria Mark Center, Alexandria Virginia



Needs in MMV

- Long-term stability monitoring
- Rapid response to leakage
- Chemical species analysis in well-heads
- P & T monitoring in injection wells

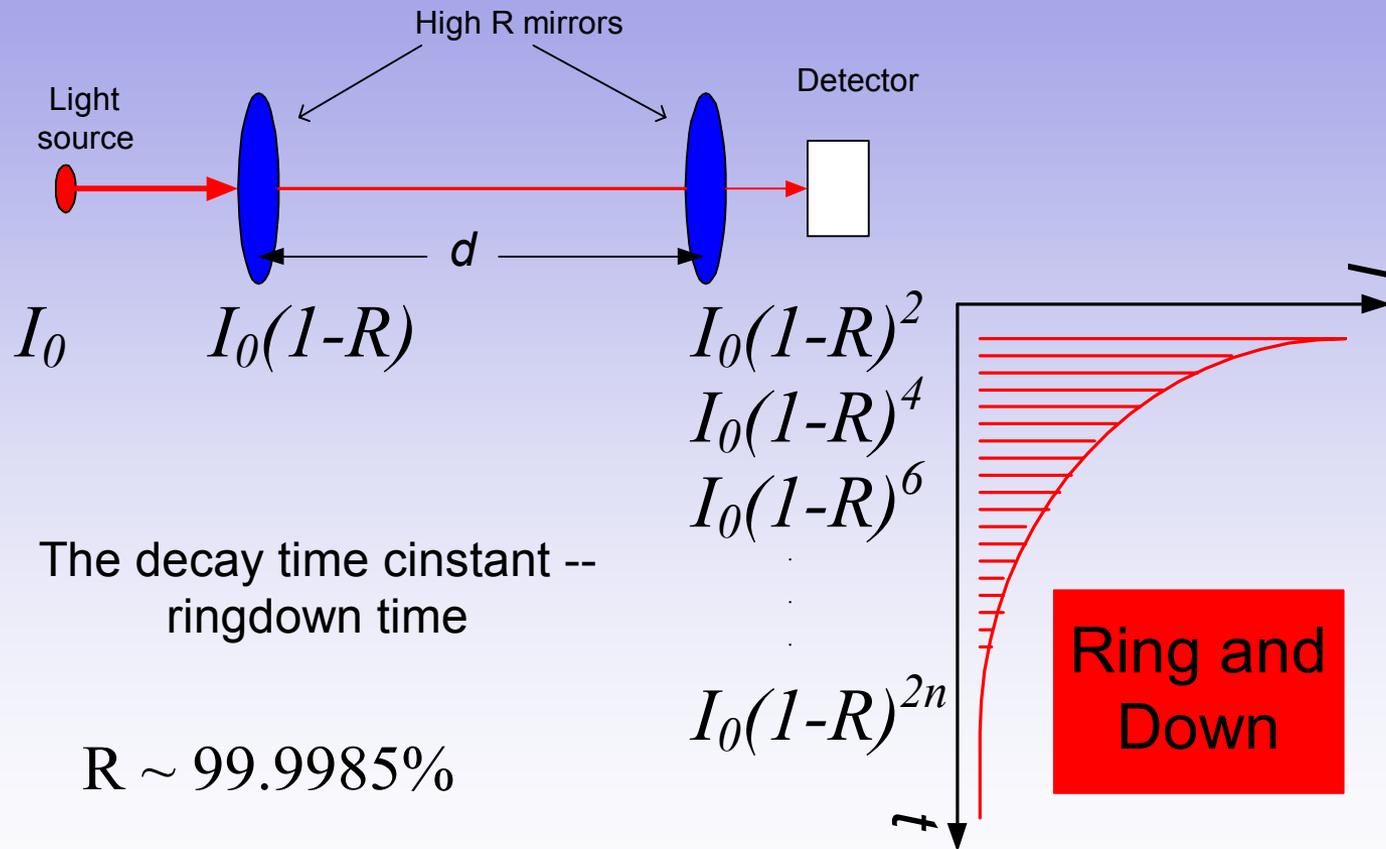
Challenges in MMV

- Small variation of CO₂ in a high concentration base (~370 ppm)
- Multiple points, concurrent measuring P & T in injection wells
- Deployment of conventional P & T monitors

Potentials Offered by Cavity Ringdown Technology

- Concurrent monitoring CO₂, CH₄, et al
- Measurement of C-13 in CO₂
- Measurement of tracers
- Optical fiber pressure and temperature sensors

Cavity Ringdown Spectroscopy (CRDS)



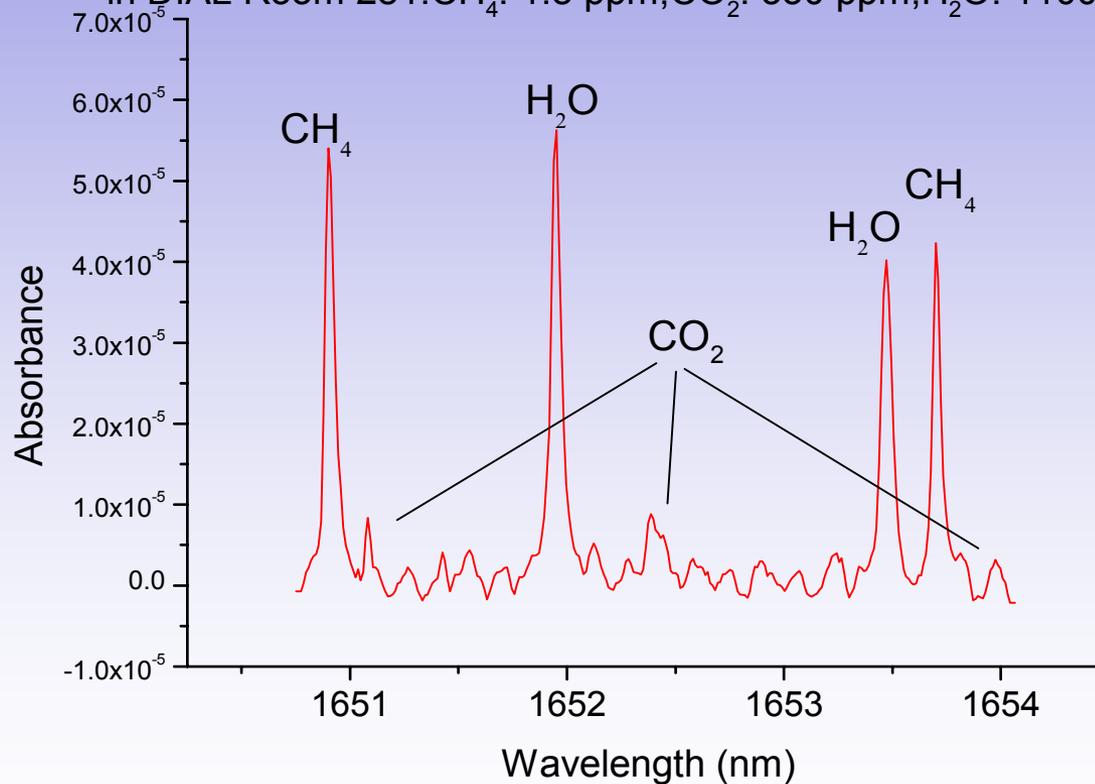
Principle and Merits of CRDS

- Ringdown does not measure light intensity
- Ringdown measures changes of time constants resulting from any interaction occurred in the ringdown *cavity*

- **Ultra Sensitive** (ppm to ppt levels)
- **Highly Selective** (absorption, fingerprints)
- **Fast Response** (< 1 second)
- **Robust** (in high Temp & vibration)
- **Calibration Free** (absolute measurements)

Development of a Real-Time Portable CO₂ Monitor

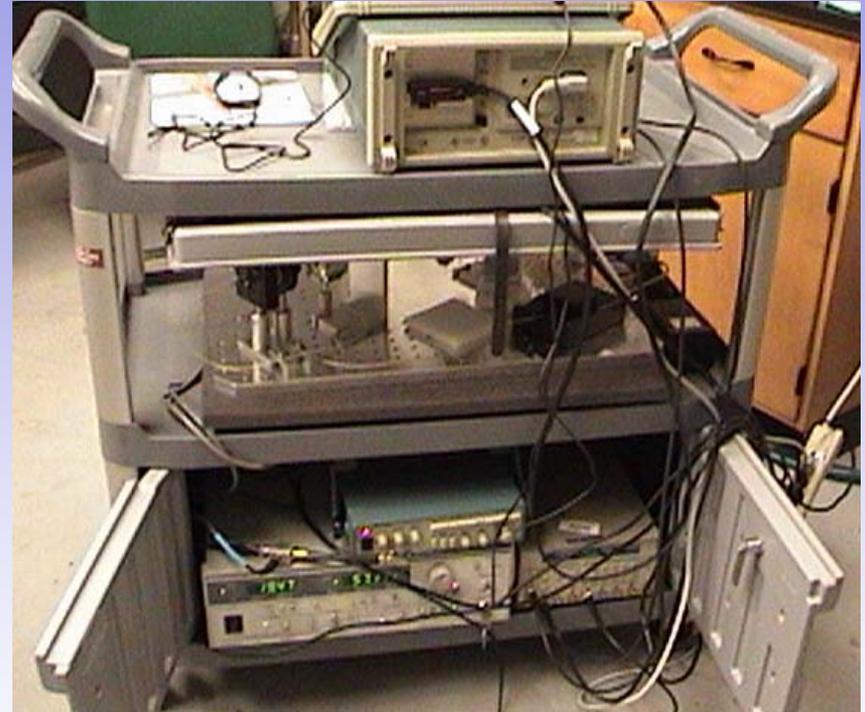
Absolute Measurements of Atmospheric CH₄, CO₂, and H₂O
in DIAL Room 281: CH₄: 1.8 ppm, CO₂: 350 ppm, H₂O: 11000 ppm



A Standalone Unit for Atmospheric CH_4 , CO_2 , and H_2O

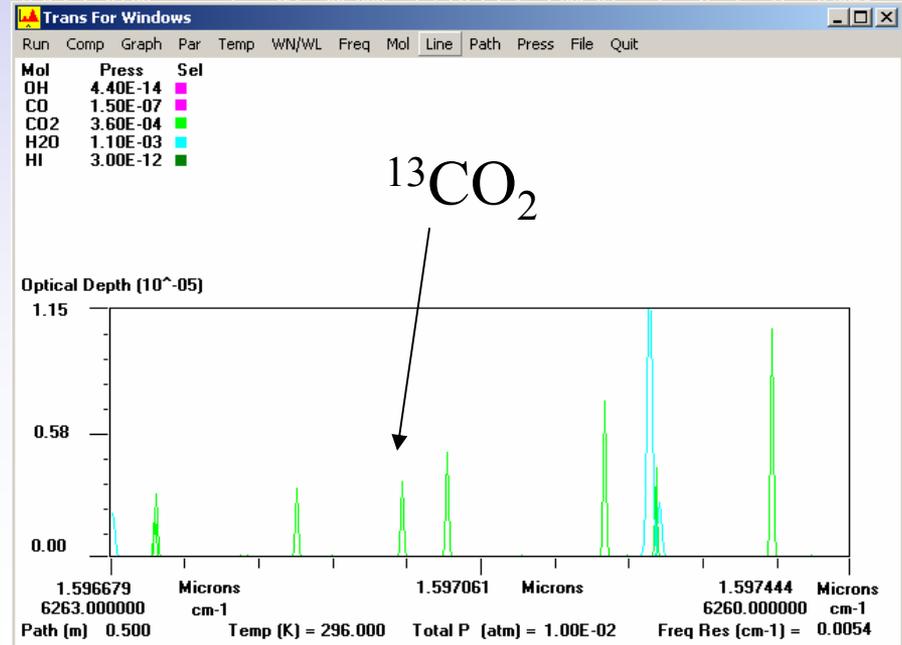
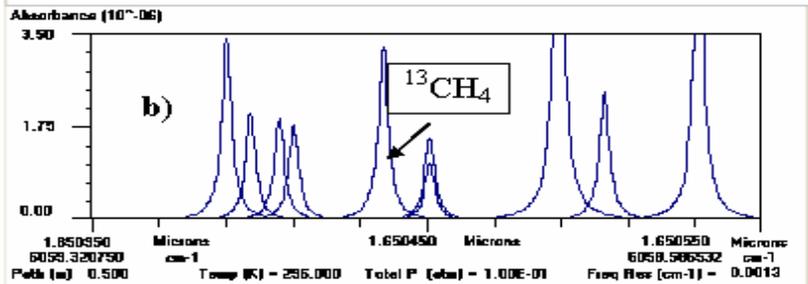
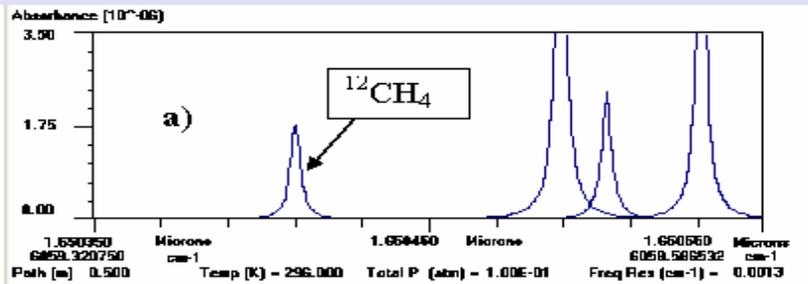
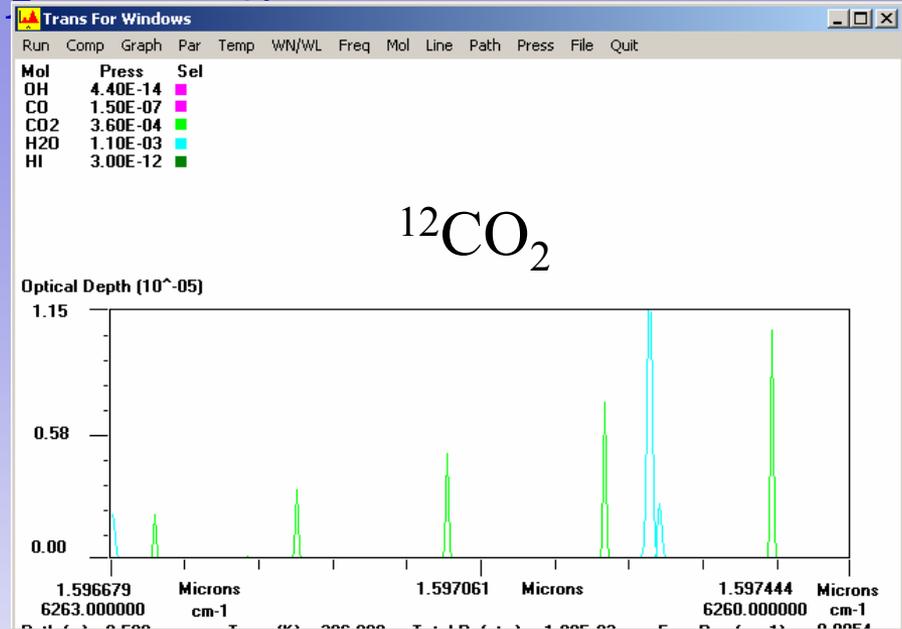
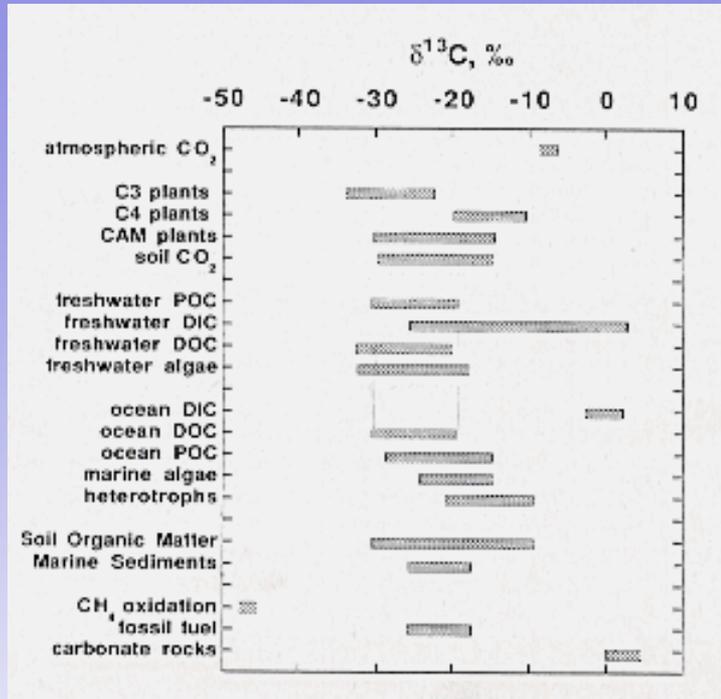


a) Front view

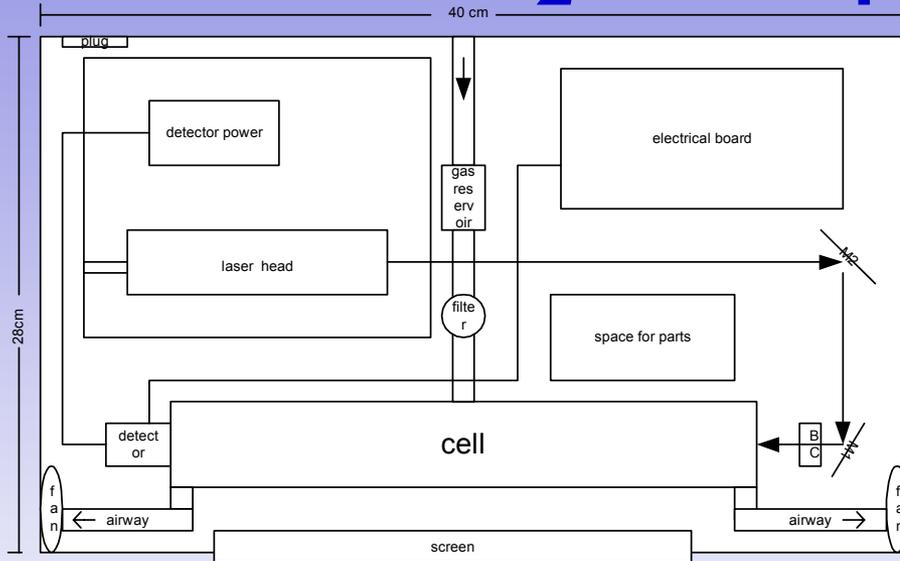


(b) Rear view

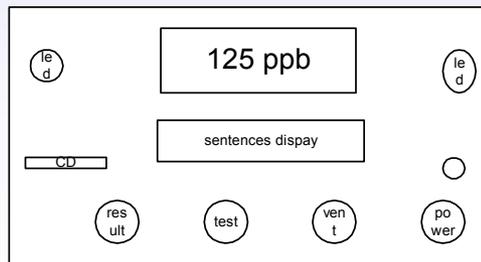
C-13 Isotope by CRDS



Ringdown Spectrometer for CO_2 , CH_4 , and C-13

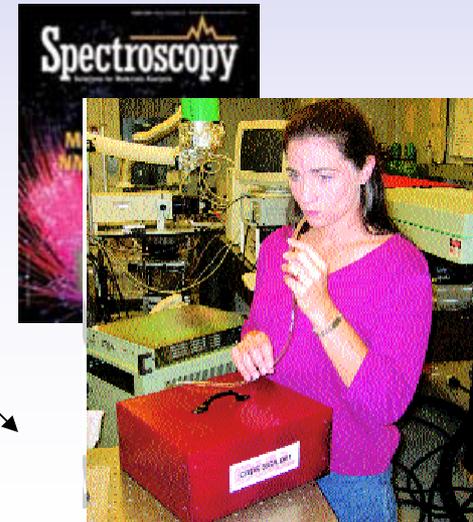


CO_2 : 300-2500 ppm
 0.3 - 25 ppm
 1 per mil for δ C-13
 CH_4 : 0.5-1 ppm



front panel

size

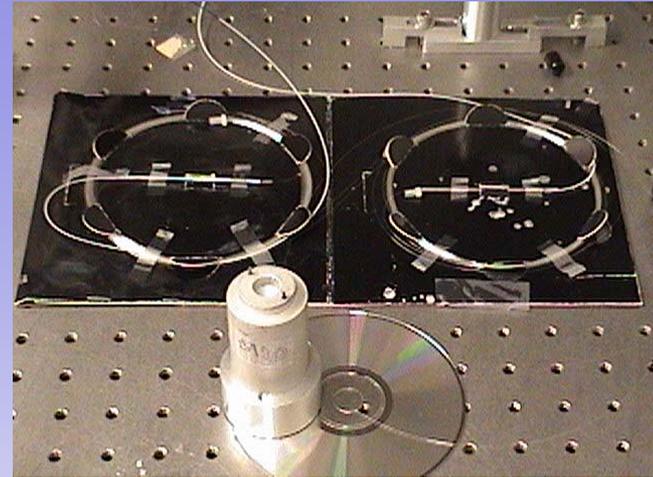
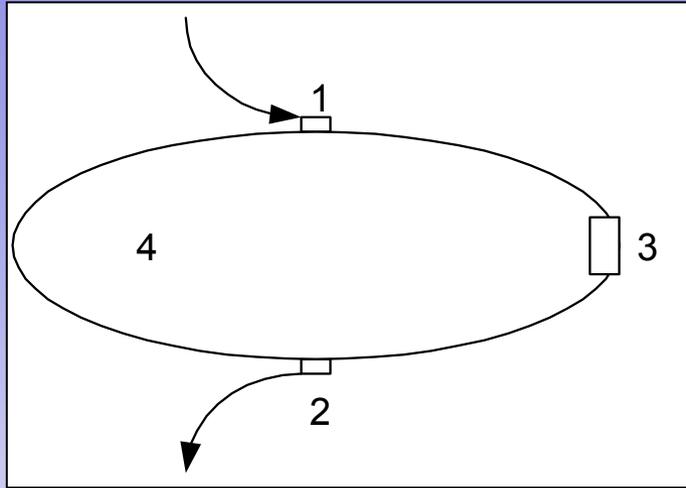


COURTESY OF DIAL

From CRDS to “Ringdown” Concept in General

- From Spectroscopy (chemical sensors)
to general application (physical sensors)
- Ringdown is a detectivity enhanced method, in which a measurement is performed in a time domain and repeatedly occurred more than 10,000 fold in a single event.
- Fiber Ringdown Pressure Sensors

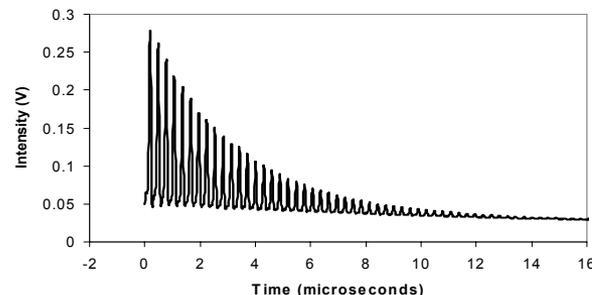
Fiber Ringdown Concept



- 1:light beam coupled into the loop;
- 2:optical signal coupled to a photodetector;
- 3:sensor head;
- 4:fiber loop.

$$I = I_0 e^{-\frac{c}{nL}At} \longrightarrow \tau_0 = \frac{nL}{cA}$$

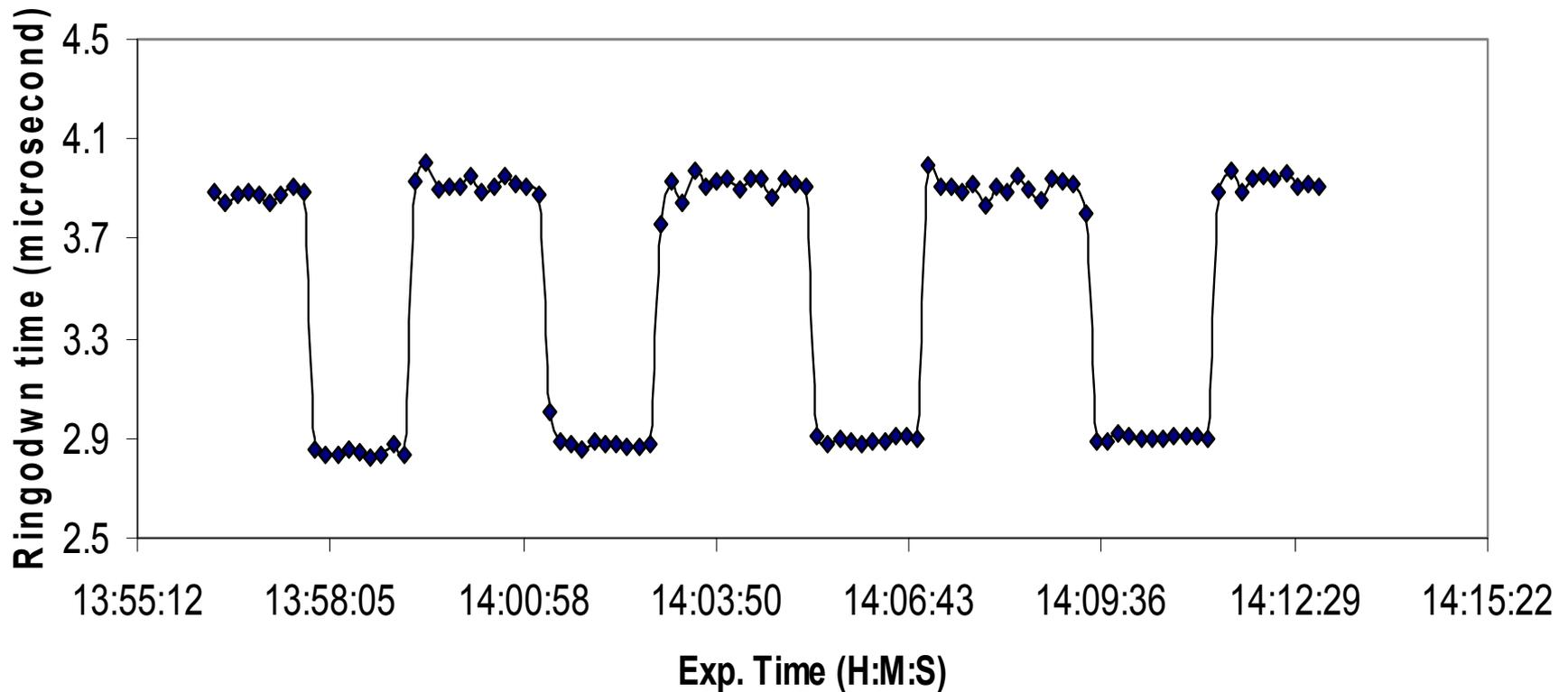
B: any event resulting in an optical loss



$$\tau = \frac{nL}{c(A+B)}$$

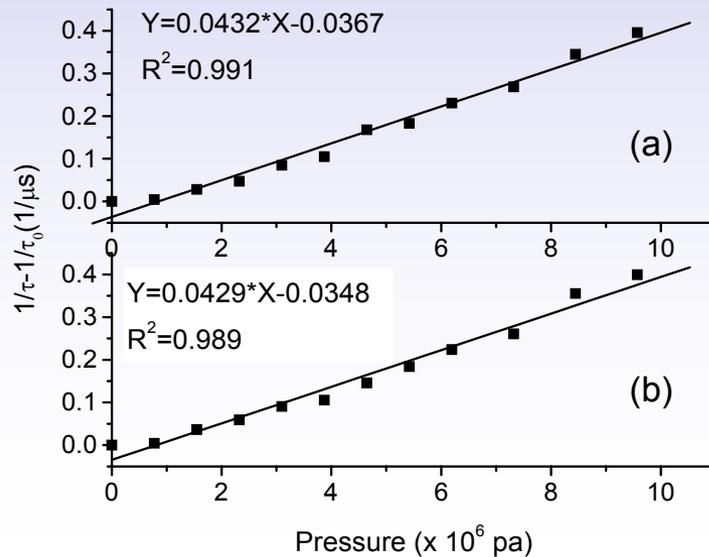
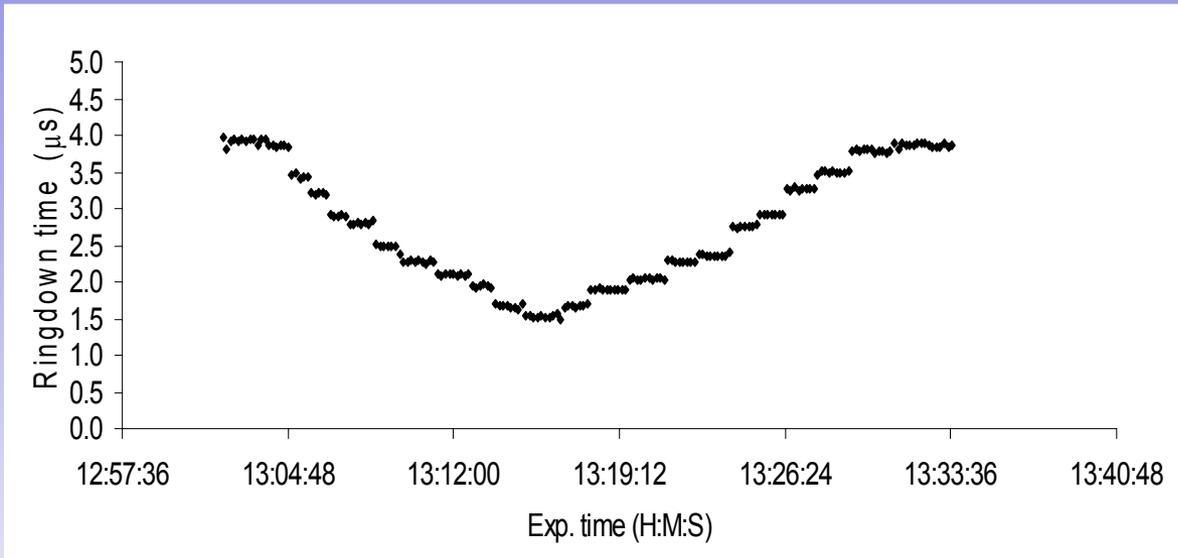
Fiber Ringdown Pressure Sensors

Sensor's Response and Repeatability



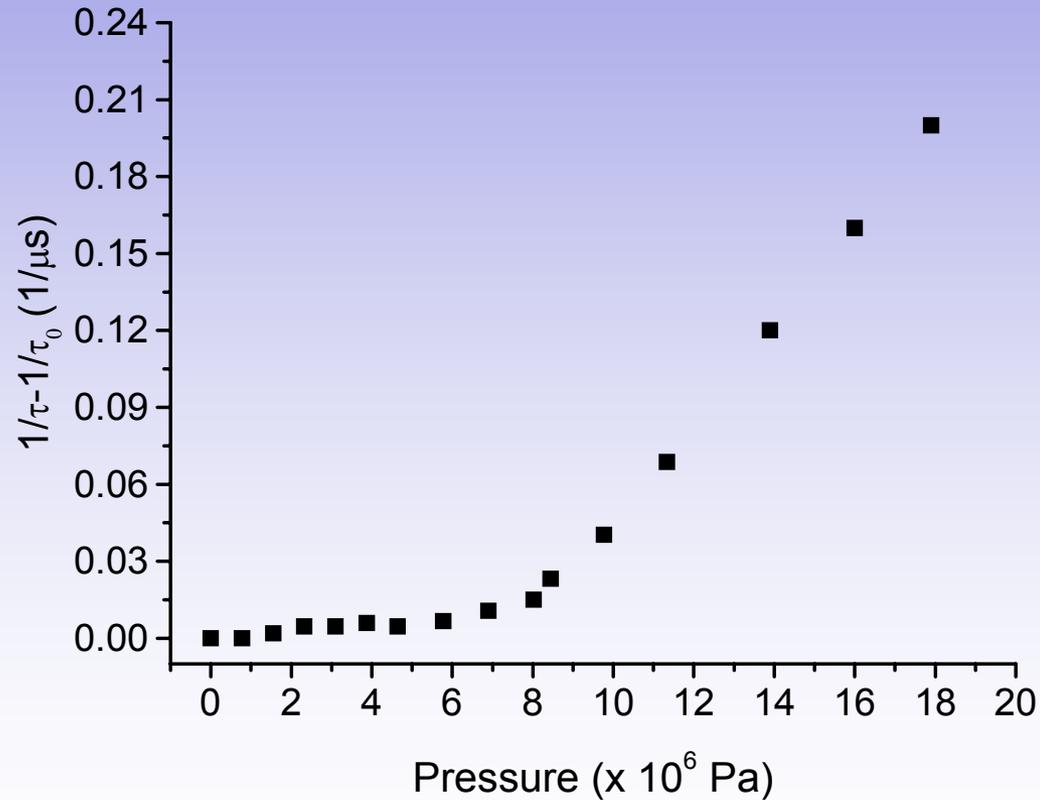
Fiber Ringdown Pressure Sensors

Sensor's reversible response



Fiber Ringdown Pressure Sensors

Measuring Pressure
up to 1.8×10^7 Pa (~ 2500 psi)



Fiber Ringdown Pressure Sensors

Current Fiber Pressure Sensors:

- Mainly based on FFPI or FBGs
- Small measuring range (< 6000 psi)
- Low temperature tolerance (< 1000 K)
(1 bar = 14.5 psi)

Fiber Ringdown Pressure Sensors:

- Using conceptually new fiber ringdown technique
- Large measuring range (0 - 20,000 psi)
- High temperature tolerance (77-1900 K)
- Rapid response (< 1 second)
- Light weight, small size, and low cost
- Immunity to EM interference

Details:

Optics Letters 2004 (Feb.)
Applied Optics 2004(Dec.)

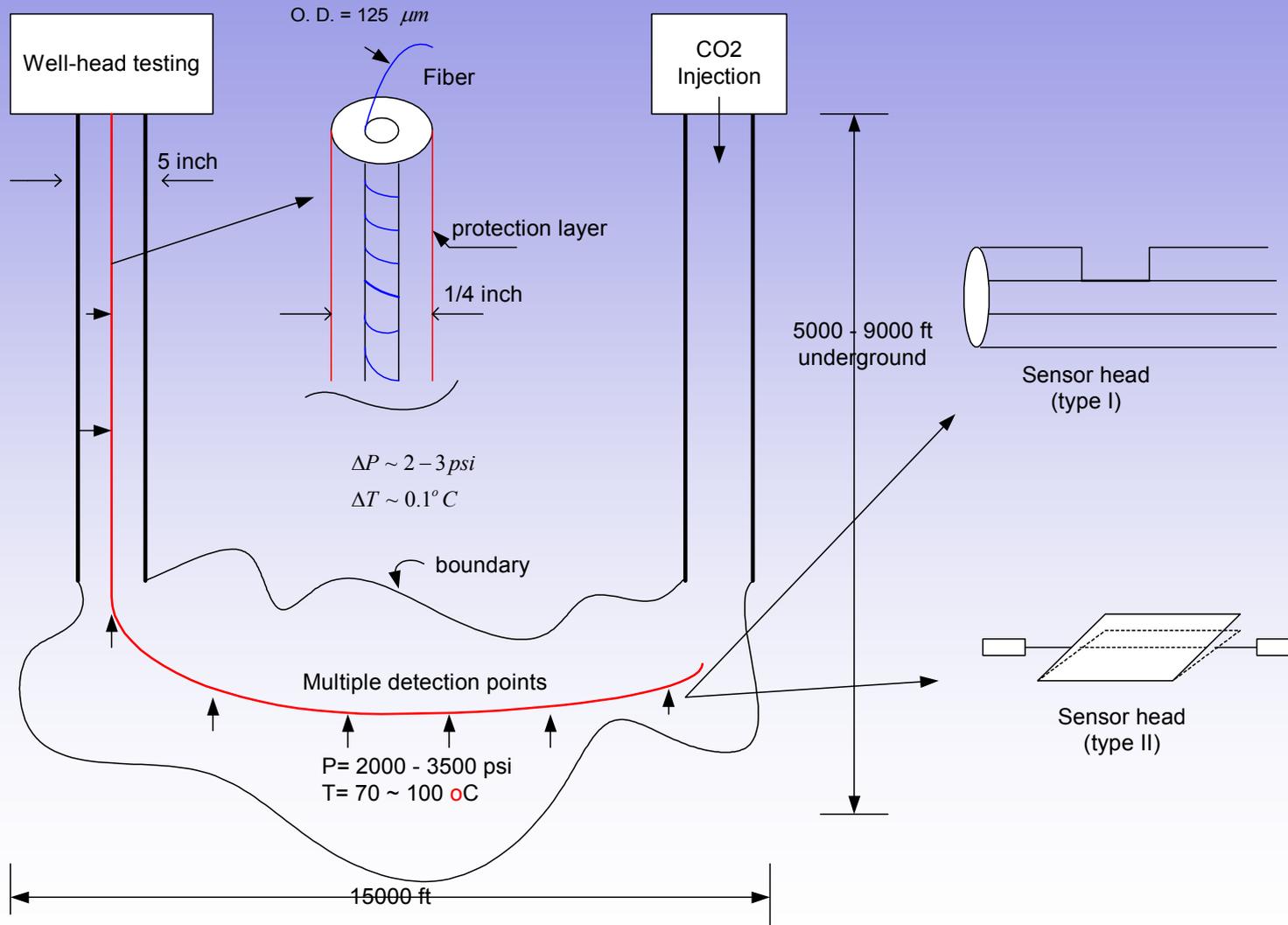
“Teams Try New Approaches to Fiber Sensors”

“Tough fiber sensor survives extremes”

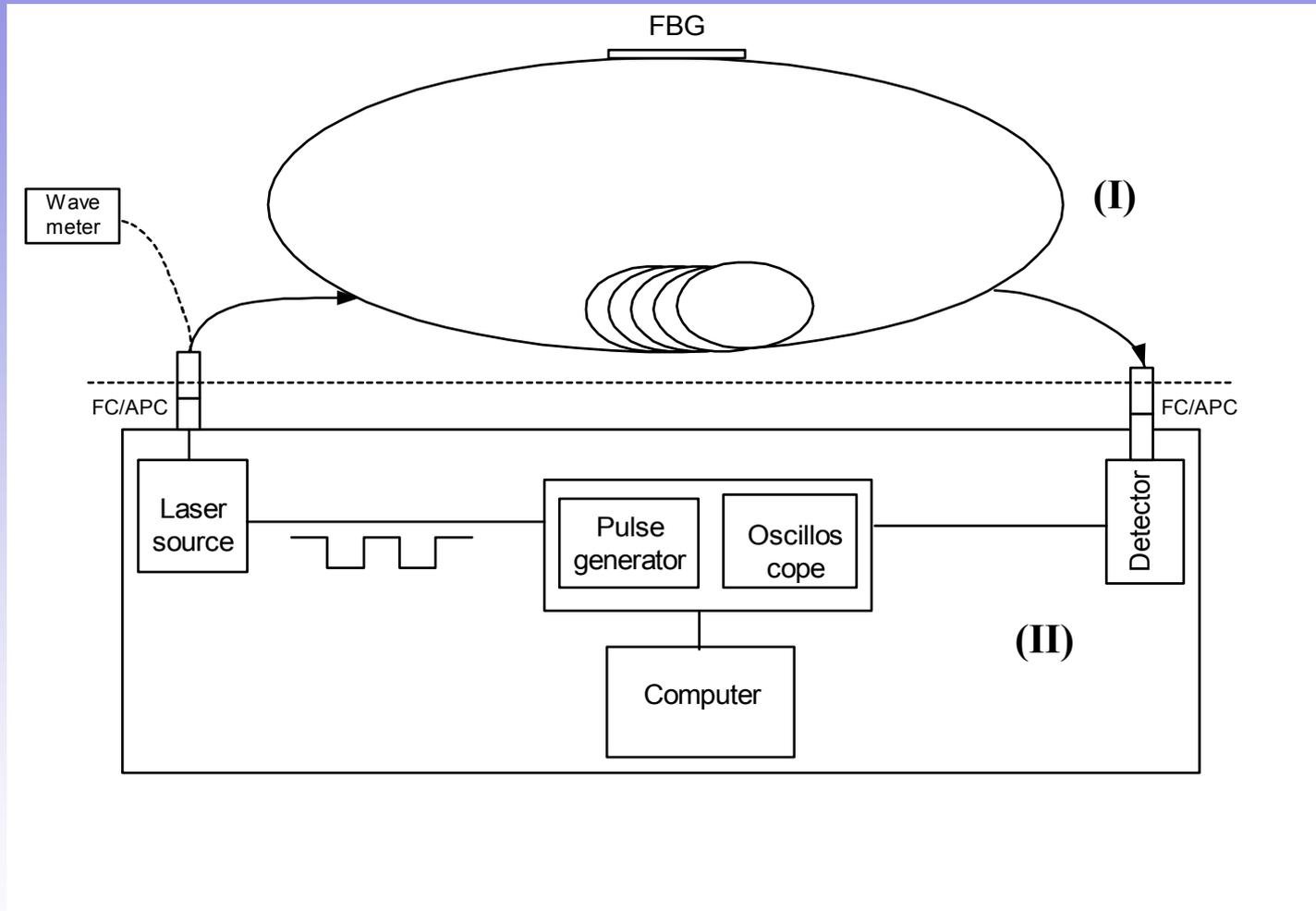


Fiber Ringdown Pressure Sensors for CS

- Teamed with TX BEG



Fiber Ringdown Temperature Sensors for CS

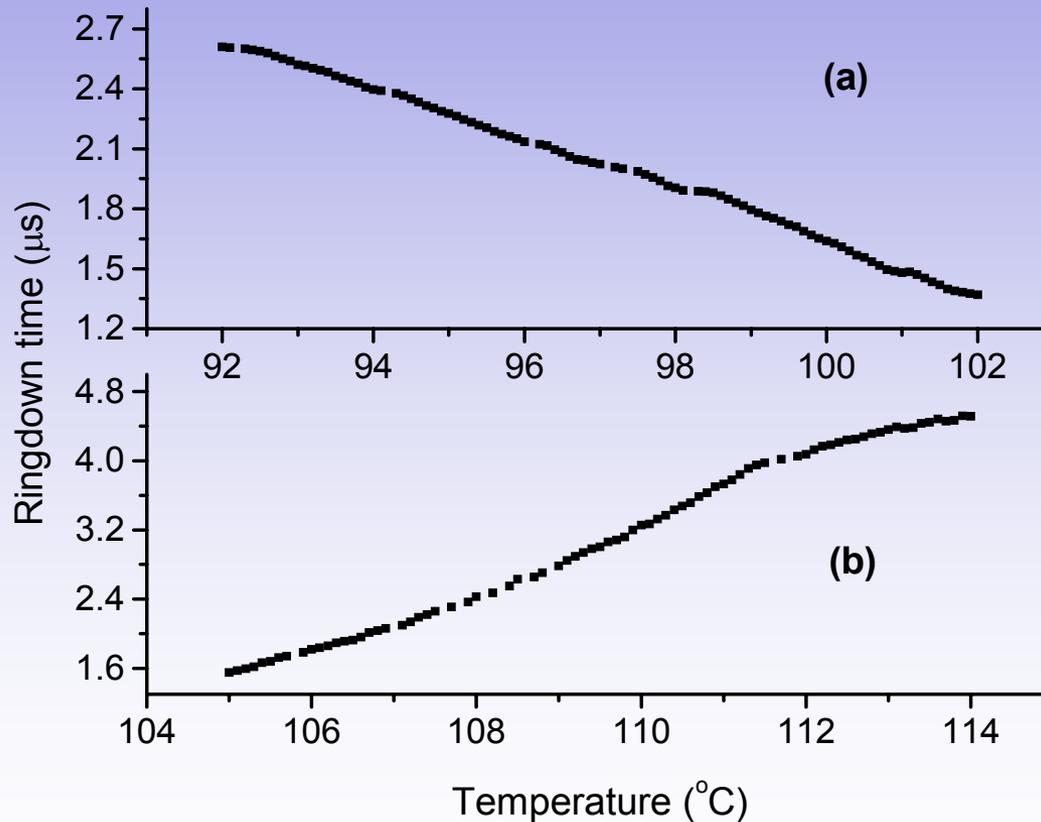


Schematic of a typical fiber grating loop ringdown temperature sensor.
Section I: the fiber grating loop with an FBG as the sensing element;
Section II: the sensor's control portion

Fiber Ringdown Temperature Sensors for CS

Type I: High Sensitivity Sensors

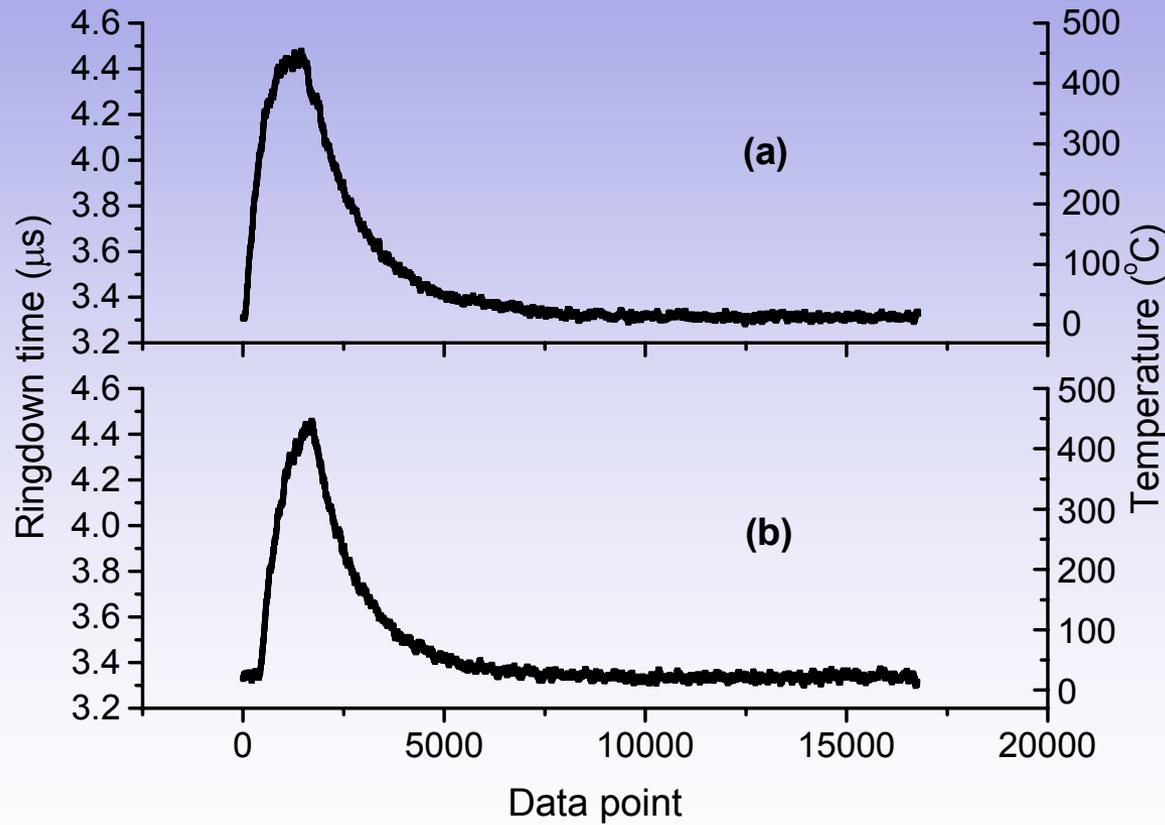
0.06 °C



Fiber Ringdown Temperature Sensors for CS

Type II: Large Measuring range Sensors

21 – 450 °C



Acknowledgements

US Department of Energy
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TX BEG